RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SWMU 49
Monitored Natural Attenuation Sampling Baseline Report

Prepared for:

USACE Baltimore District
10 S. Howard St.
Baltimore, MD 21201

Prepared by:

CB&I Federal Services LLC
4696 Millennium Dr., Suite 320
Belcamp, MD 21017

Draft Document **July 2015**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF APPENDICES

The Appendices are Included on a CD Located at the Back of This Report

LIST OF ACRONYMS AND ABBREVIATIONS

°C .....degrees Celsius
µg/L.....micrograms per liter
bgs.....below ground surface
CB&I.....CB&I Federal Services LLC
CMO .....Corrective Measures Objective
COC .....Contaminant of Concern
CT .....carbon tetrachloride
ft bTOC .....feet below top of casing
ft msl .....feet above mean sea level
ft .....foot or feet
HHRA .....Human Health Risk Assessment
MCL.....Maximum Contaminant Level
MDL.....Method Detection Limit
mg/L.....milligrams per liter
MNA .....Monitored Natural Attenuation
MRL.....Method Reporting Limit
MS.....Matrix Spike
mS/cm .....milliSiemens per centimeter
MSD.....Matrix Spike Duplicate
mV.....millivolts
NTU .....Nephelometric Turbidity Unit
ORP.....Oxidation-Reduction Potential
Parsons .....Parsons Engineering Science, Inc.
PID .....Photoionization Detector
POC.....Point of Compliance
QA/QC .....Quality Assurance/Quality Control
RCRA.....Resource Conservation and Recovery Act
RFAAP.....Radford Army Ammunition Plant
RFI .....RCRA Facility Investigation
RG.....Remedial Goal
SWMU .....Solid Waste Management Unit
TCE.....trichloroethene
TCL.....Target Compound List
TOC.....Total Organic Carbon
URS.....URS Corporation
USACE .....U.S. Army Corps of Engineers
USATHAMA.U.S. Army Toxic and Hazardous Materials Agency
USEPA.....U.S. Environmental Protection Agency
VDEQ .....Virginia Department of Environmental Quality
VI .....Verification Investigation
VOC.....Volatile Organic Compound

1.0 INTRODUCTION

CB&I Federal Services LLC (CB&I) was contracted by the U.S. Army Corps of Engineers (USACE) to perform Monitored Natural Attenuation (MNA) groundwater sampling at Solid Waste Management Unit (SWMU) 49 (RAAP-13), the Red Water Ash Burial #2, at Radford Army Ammunition Plant (RFAAP), Radford, VA. This report contains a description of the activities involved in the baseline MNA groundwater sampling conducted in January 2015. This report includes an analysis of the results of the baseline data and a summary of the baseline sampling.

1.1 Purpose and Scope

Groundwater at the SWMU 49 study area has been investigated from the mid-1990s through 2013 and has been fully characterized and delineated. Based on the contamination assessment and the human health risk assessment (HHRA) performed in the *Draft SWMU 48/49 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report* (CB&I, 2014a), carbon tetrachloride (CT) and trichloroethene (TCE) are the primary contaminants of concern (COCs) that are contributing potential future industrial and residential risk at the combined study area. Results from the MNA analysis conducted for the SWMU 49 study area groundwater indicated that MNA processes including biodegradation, sorption, dilution, dispersion, and chemical stabilization are occurring in groundwater at the SWMU 49 study area.

The MNA program was developed and conducted in accordance with U.S. Environmental Protection Agency (USEPA) and Virginia Department of Environmental Quality (VDEQ) approved *Draft SWMU 48/49 RFI Report* (CB&I, 2014a) and the *Draft Final SWMU 49 MNA Groundwater Monitoring Work Plan* (CB&I, 2014b). The corrective measures objectives (CMOs) and remedial goals (RGs) were developed in the *Draft SWMU 48/49 RFI Report* (CB&I, 2014a). The site-specific CMO for SWMU 49 is to reduce COC concentrations to below RGs/maximum contaminant levels (MCLs) so as to not adversely impact future beneficial use of groundwater; and to the extent practicable, a goal of restoring site groundwater to the most beneficial use.

The objectives of the MNA program are to:

- Measure and track the reduction of:
  - CT and TCE to levels below the RGs as defined in **Table 1-1**.

Table 1-1
SWMU 49 Groundwater Remedial Goals

Chemical of Interest	Groundwater RG (µg/L)	Groundwater RG Source(*)
Carbon Tetrachloride	5.0	MCL
Trichloroethene	5.0	MCL

*Remedial goals (RGs) are also the Maximum Contaminant Levels (MCLs) listed in the USEPA 2011 Edition of the Drinking Water Standards and Health Advisories (USEPA, 2011).

- Monitor and evaluate the daughter products of the COCs to determine the progress (effectiveness and timeliness) of the degradation process.

1.2 Site Description and Background

SWMU 49 is located in the southeastern portion of the RFAAP Horseshoe Area, east of the main bridge over the New River. As shown on **Figures 1-1 and 1-2**, the study area is situated on a bluff approximately 120 feet (ft) above and overlooking SWMU 13 and the New River. The SWMU 49 study area is approximately 75 ft long by 83 ft wide. The site is adjacent to and used to be a combined study area with SWMUs 48, 50, and 59.

As discussed in CB&I (2014a,b), SWMU 49 reportedly received 10 tons of red water ash during its active period. However, the results of environmental sampling to date indicate that the red water ash was likely disposed of in the disposal trenches associated with neighboring SWMU 48. Conversely, sampling indicates that the oily wastewater associated with SWMU 48 was disposed of in the SWMU 49 area.

LEGEND

- SWMU 49 Boundary
- Other SWMU Boundary
- Installation Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.

Scale:

0 500 1,000 2,000 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millenium Drive, Suite 320
Belamp, Maryland 21017

FIGURE 1-1

SWMU 49 Site Location Map

Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_49_MNA_Report\RFAAP_Fig1-1_SWMU49_SiteLocMap_MNA_rpt.mxd (3/19/2015)

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Fence
- 10 ft Contour Line
- SWMU 49 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.

Scale:
0 125 250 500 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millenium Drive, Suite 320
Belamp, Maryland 21017

FIGURE 1-2
SWMU 49
Site Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_49_MNA_Report\RFAAP_Fig1-2_SWMU49_Site_Map_MNA_rpt.mxd (5/20/2015)

2.0 PHYSICAL CHARACTERISTICS

2.1 Topography

As illustrated on **Figures 1-2 and 2-1**, the land surface at SWMU 49 gently slopes from 1,830 ft above mean sea level (ft msl) on the north side, to approximately 1,816 ft msl on the southeast side of the site.

2.2 Surface Water

SWMU 49 is located on a bluff approximately 120 ft above and overlooking SWMU 13 and the New River. Based on topography, surface water runoff is expected to flow approximately 700 ft south to the New River.

2.3 Geology

2.3.1 Regional Geology

SWMU 49 is located in the New River Valley, which crosses the Valley and Ridge Province approximately perpendicular to the regional strike of bedrock, and cross cuts Cambrian and Ordovician limestone or dolostone. Deep clay-rich residuum is prevalent in areas underlain by carbonate rocks. The valley is covered by river floodplain and terrace deposits; karst topography is dominant throughout the area. A more detailed description of the regional geology is presented in the *RFAAP Master Work Plan* (URS, 2003).

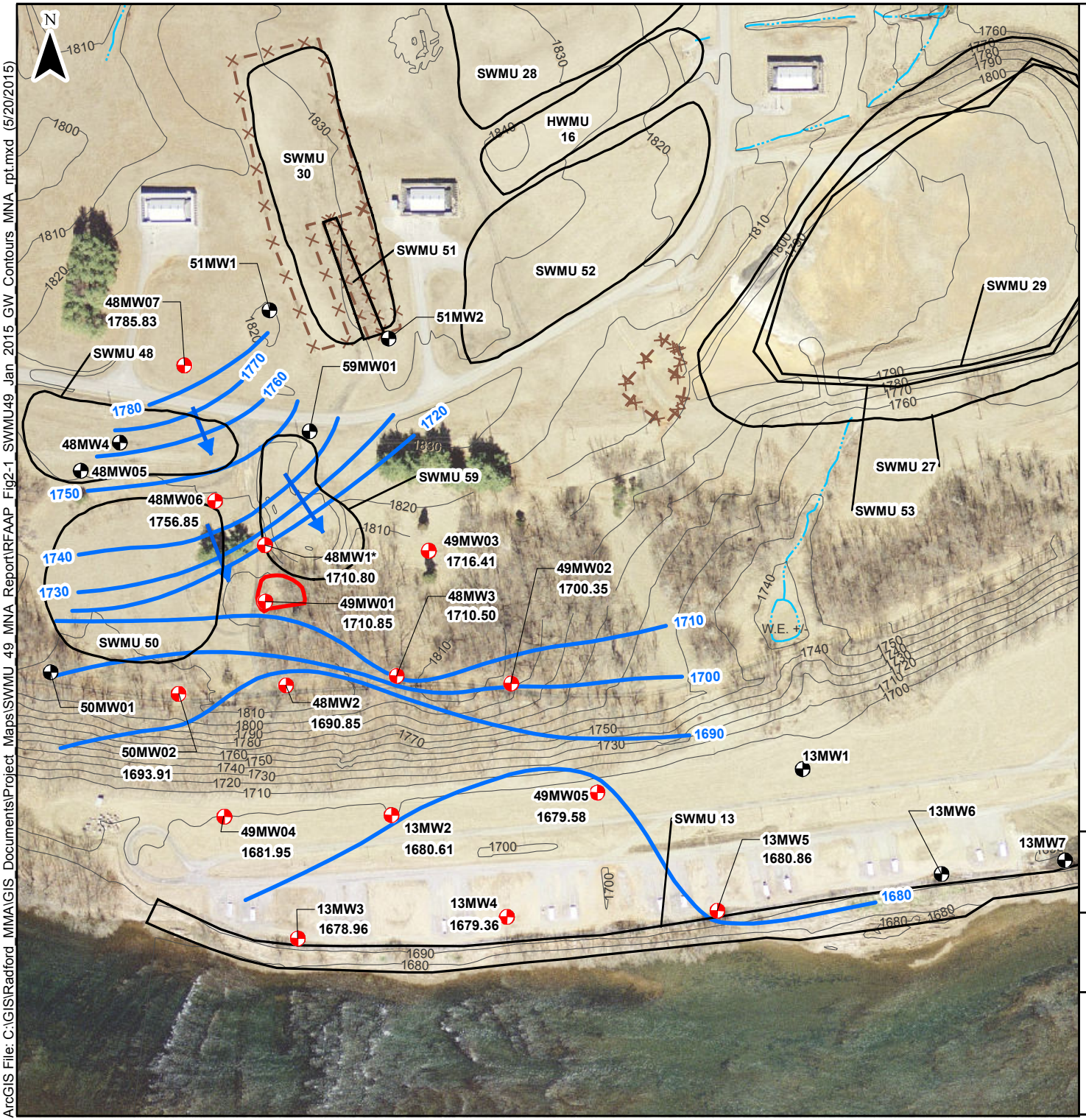
2.3.2 Site-Specific Geology

Lithologic characterization of the subsurface at SWMU 49 was performed during the advancement of soil borings and monitoring well borings at the site. One soil boring (48SB05) was advanced within SWMU 49 to 37 ft in depth. In addition to 48SB05, two monitoring wells were installed directly north and south of the target study area: 48MW1 and 48MW2, respectively. Plan and cross-section views of lines A-A' and B-B' that run through the adjacent sites of 48, 50, and 59 are presented on **Figures 2-2 and 2-3.** As depicted, the subsurface geology consists of alluvium and residual deposits comprised of clay and silt with some sand and gravel overlying bedrock. 48MW1 was advanced to 154 ft below ground surface (bgs), with the bedrock elevation encountered at 72 ft bgs. 48MW2 was advanced to 133.7 ft bgs, with the bedrock elevation encountered at approximately 41 ft bgs. Depths to bedrock were directly measured at the monitoring well borings. Bedrock elevations ranged from approximately 1,745 to 1,776 ft msl, with the bedrock surface sloping to the north.

Depth to competent bedrock at the site ranges from approximately 41 to 72 ft. A saprolitic layer, formed from in situ weathering of the carbonate bedrock, immediately overlies the competent bedrock. The saprolite is up to 10 ft in thickness.

Bedrock consists of highly fractured interbedded siltstone, limestone, and dolostone of the Elbrook Formation. The Max Meadows Breccia is evident in outcrops along the slope leading to the river. In the outcrop along the slope, the tectonic breccias and the limestone and dolostone are highly weathered with many solution cavities.

The unconsolidated sediment immediately overlying the saprolite consists of alluvial deposits. Alluvial deposits, consisting primarily of silty sand, overly channel deposits of fine- to coarse-grained sand and gravel (river jack). These Paleo-channel deposits rest directly on the saprolite. Portions of the disposal areas contain fill material to depths of 9 to 10 ft bgs.



LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Fence
- 10 ft Contour Line
- Groundwater Flow Direction
- Groundwater Contour
- SWMU 49 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Water levels (in feet above mean sea level) measured in January 2015.
3) Well 48MW1 was excluded from contouring (see Section 4.1).

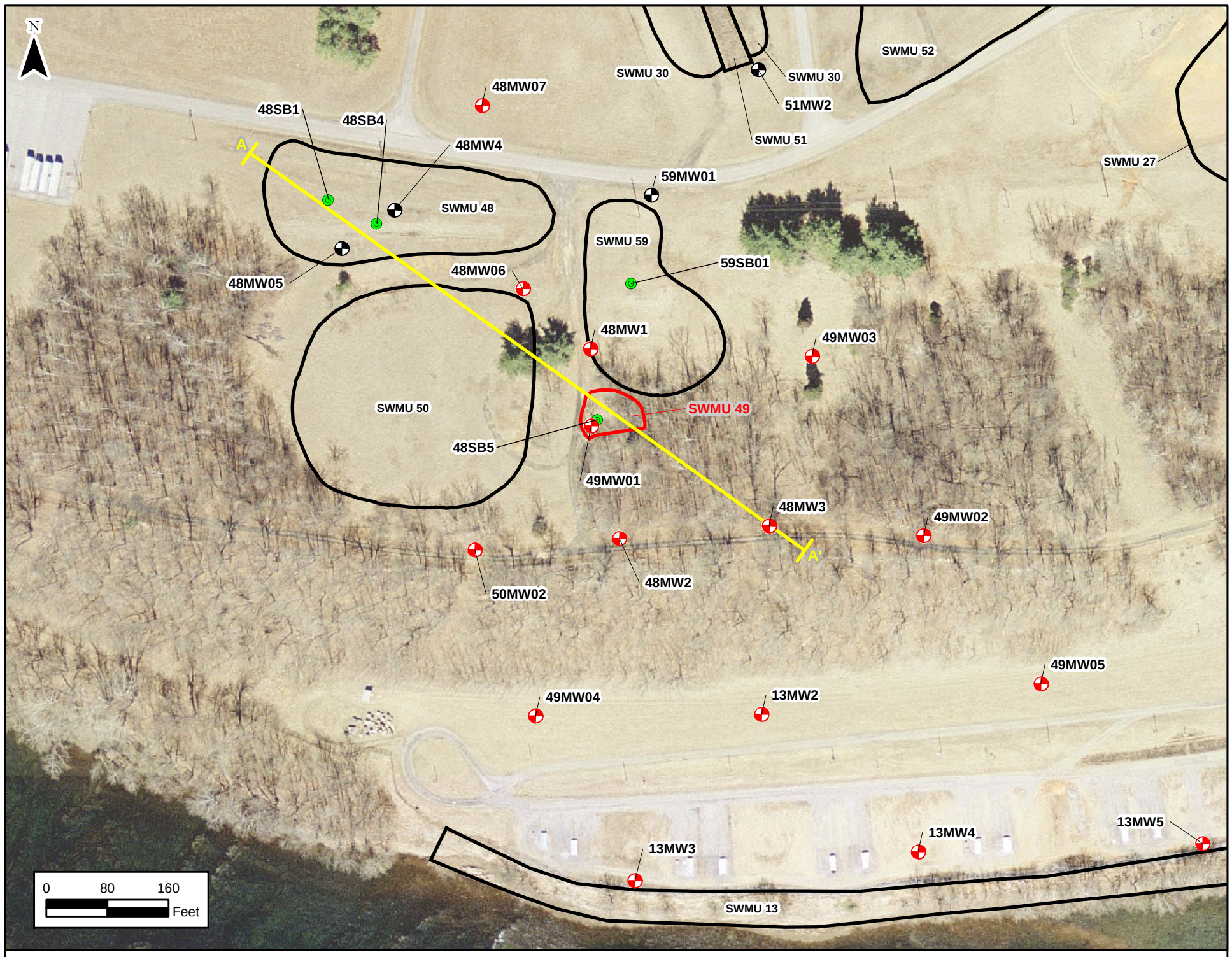
Scale:
0 125 250 500 Feet

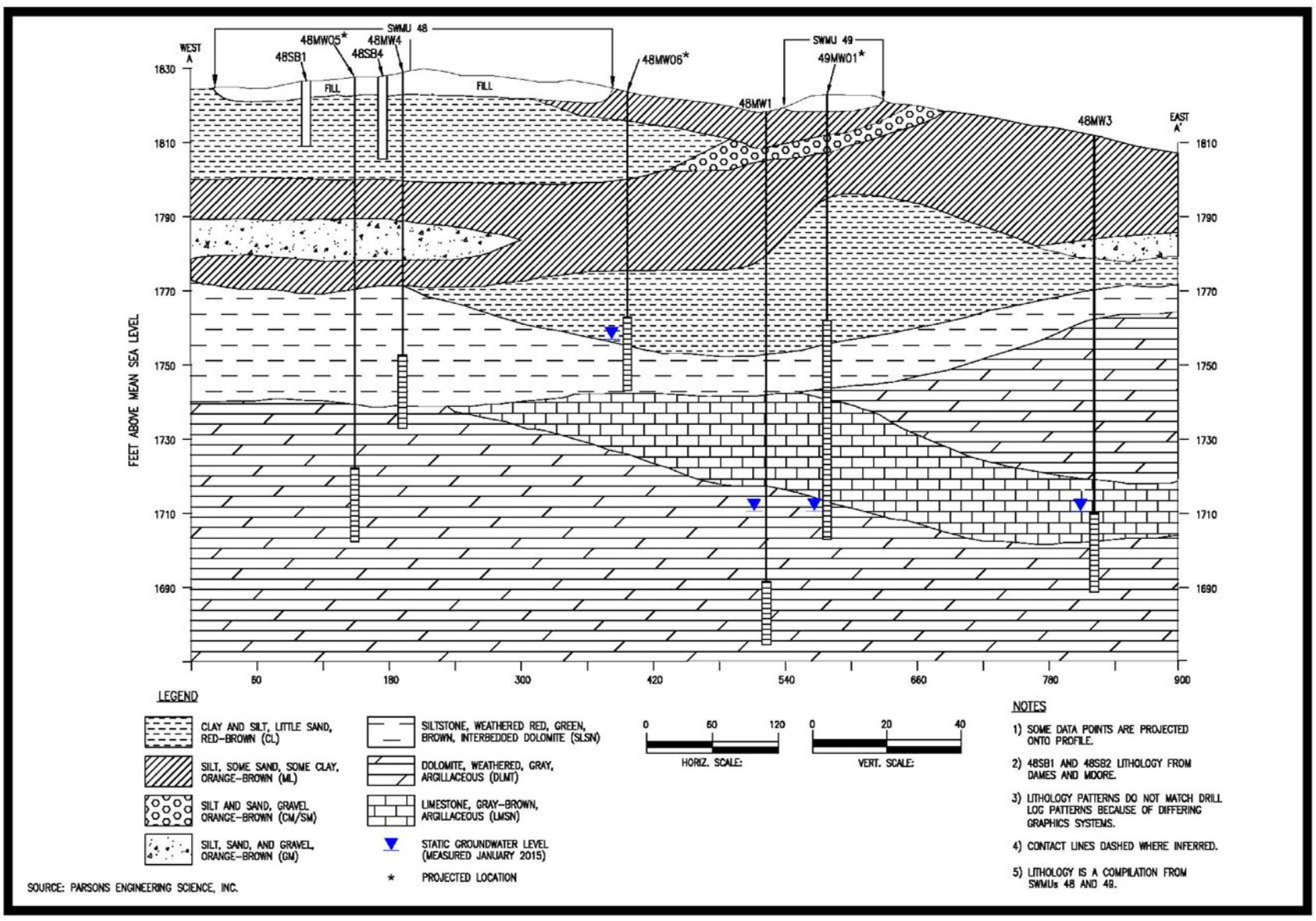
U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millenium Drive, Suite 320
Belamp, Maryland 21017

FIGURE 2-1
SWMU 49
Potentiometric Surface Map - January 2015
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_49_MNA_Report\RFAAP_Fig2-1_SWMU49_Jan_2015_GW_Contours_MNA_rpt.mxd (5/20/2015)





U.S. Army Corps of Engineers

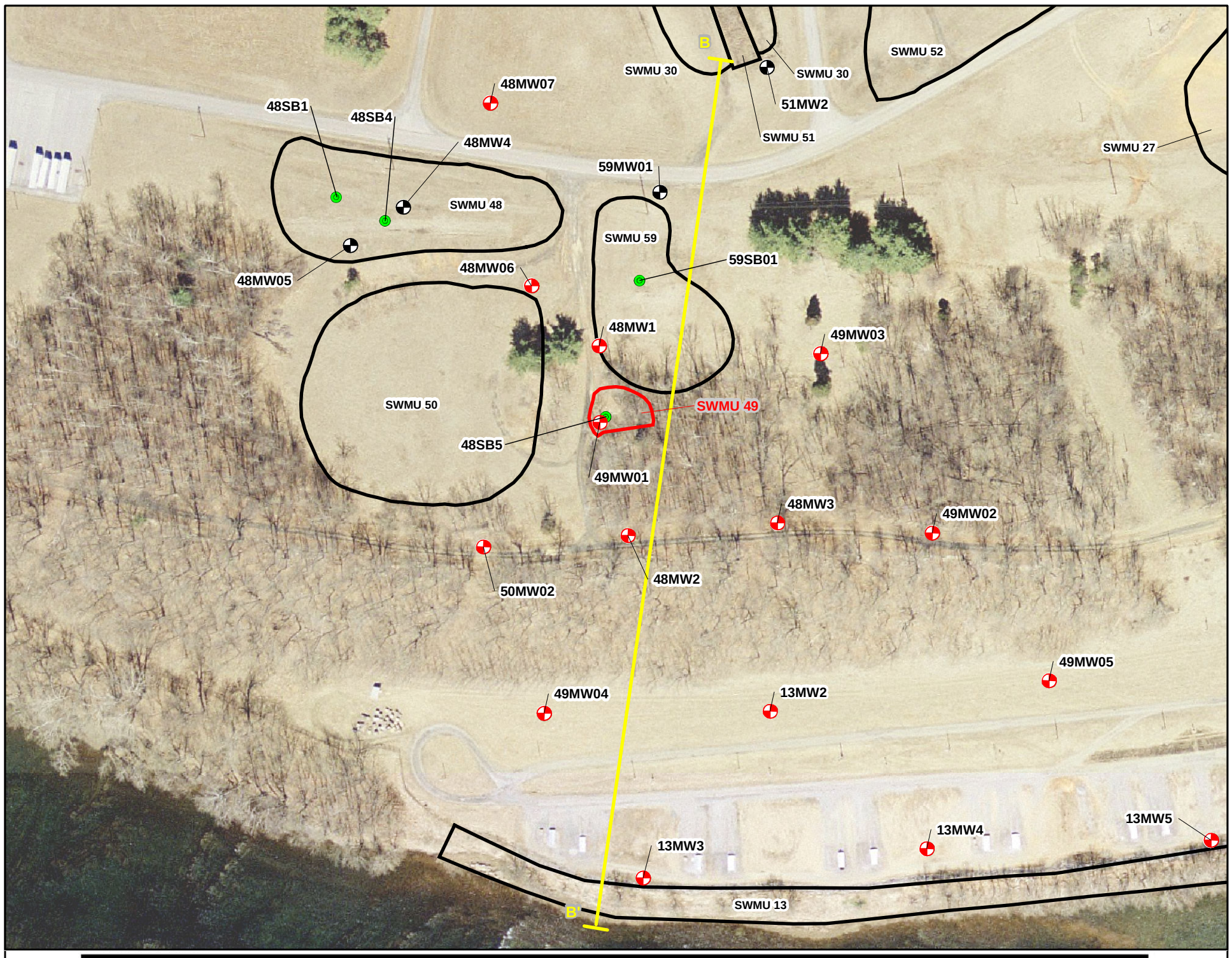
CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

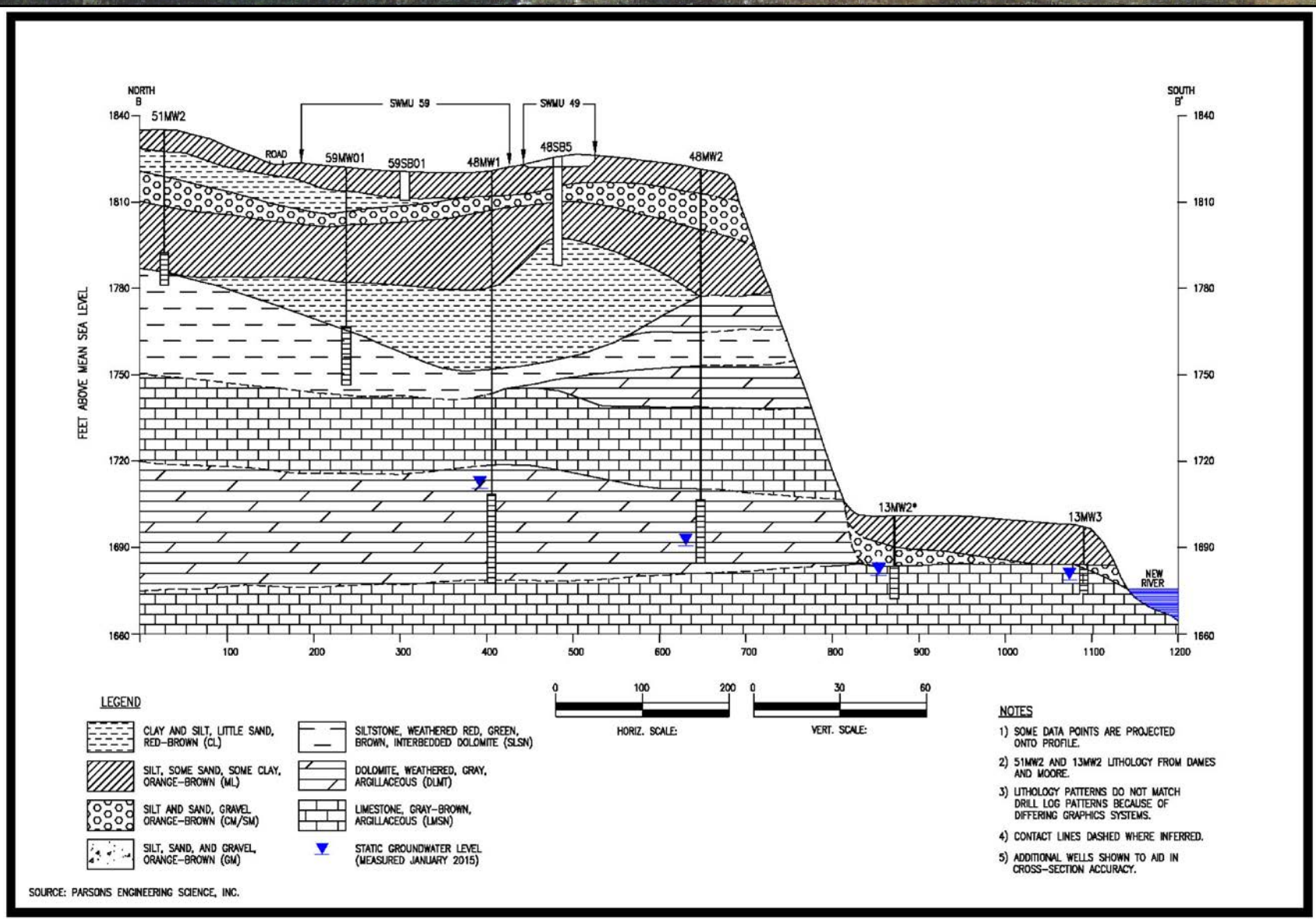
FIGURE 2-2
SWMU 49
Cross Section A-A'
Radford Army Ammunition Plant,
Radford, VA

Monitoring Well (Sampled)
Monitoring Well (Not Sampled)
Previous Investigation Soil Sample Location
Geologic Cross Section Line
SWMU 49 Boundary
Other SWMU Boundaries

Note:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section A-A' profile and soil sample locations were obtained from SWMU 48/49 Draft RCRA Facility Investigation Report (January 2014, Shaw). Distance and elevation units are in feet. Vertical exaggeration = 3.

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_49_MNA_Report\RFAAP_Fig2-2_SWMU49_XSect_AA_MNA_rpt.mxd (3/19/2015)





U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 2-3
SWMU 49
Cross Section B-B'
Radford Army Ammunition Plant,
Radford, VA

Monitoring Well (Sampled)

Monitoring Well (Not Sampled)

Previous Investigation Soil Sample Location

Geologic Cross Section Line

SWMU 49 Boundary

Other SWMU Boundaries

Note:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section B-B' profile and soil sample locations were obtained from SWMU 48/49 Draft RCRA Facility Investigation Report (January 2014, Shaw). Distance and elevation units are in feet. Vertical exaggeration = 3.3.

A more detailed discussion of the geology and soil at RFAAP is presented in Sections 3.4 through 3.7 of the *RFAAP Master Work Plan* (URS, 2003) and in the *Facility-Wide Background Study Report* (IT, 2001).

2.4 Hydrogeology

2.4.1 Regional Hydrogeology

Geologically, the Appalachian Plateaus and Valley and Ridge Province encompass two major tectonic domains: the southern Appalachian Basin and the southeastern part of the Eastern Interior Basin. The hydrogeologic framework is based on generalized stratigraphic succession, with indurated sedimentary rocks of the Paleozoic age forming predominant units.

Groundwater flow paths are typically short, commonly extending no more than several miles in their longest dimension. The largest groundwater supplies are produced from the carbonate rocks, especially where they are associated with thick regolith, an important storage reservoir throughout the entire area. The regolith stores recharge that would otherwise be rapidly diverted to overland flow. It also slowly releases water to underlying carbonate aquifers. Because of the widespread distribution of carbonate rocks and associated regolith, abundant precipitation in a humid climate, and relatively steep hydraulic gradients, this region (and locality) is one of the major karstlands in the eastern United States.

Groundwater supplies in the Valley and Ridge Province are generally good quality compared to surface water supplies (Parsons, 1996). However, due to extended contact with minerals, many groundwater supplies contain higher levels of dissolved solids than the streams into which they discharge. Because of sinkholes and underground caverns in karst aquifers, there is a high potential for groundwater to be impacted by direct infiltration of contaminated surface water.

2.4.2 Site-Specific Hydrogeology

Monitoring wells installed at SWMU 49 were screened in both the surficial unconsolidated deposits and in the underlying bedrock. Boring logs and well construction diagrams for the SWMU 49 study area wells are presented in **Appendix A**. Water levels were measured in the wells to determine the groundwater flow direction at the site. As shown on **Figure 2-1**, the groundwater table was present below the sites in January 2015 at elevations ranging from 1678.96 to 1785.83 ft msl. A groundwater contour map has been prepared using the water level data obtained during the baseline round of groundwater sampling (**Figure 2-1**). A steep hill exists between SWMU 49 and SWMU 13 and, therefore, no monitoring wells are positioned between these sites. Contour lines shown on the figure represent lines of equal elevation of the water table; consequently, groundwater flow direction is always perpendicular to the contour lines. Groundwater at the site tends to flow south towards SWMU 13 and appears to discharge to the New River, south of the study area.

3.0 PREVIOUS INVESTIGATIONS

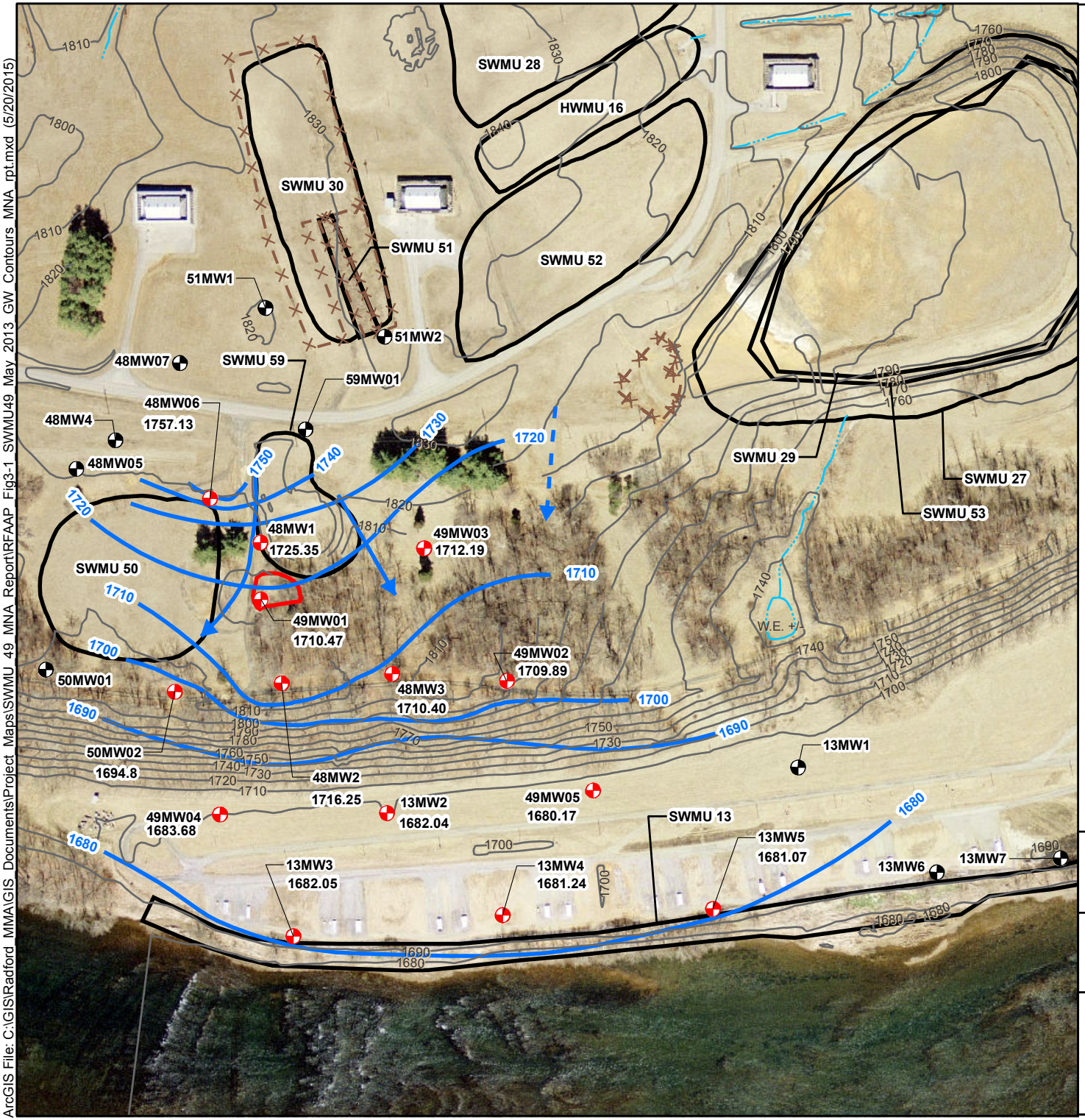
Seven previous investigations have been conducted at the previously combined study area of SWMUs 48 and 49. In 1987, a RCRA Facility Assessment was conducted to evaluate potential hazardous waste or hazardous constituent releases and implement corrective actions, as necessary (USATHAMA, 1987). In 1992, Dames and Moore performed a Verification Investigation (VI), which included surface and subsurface soil sampling and a soil gas survey to characterize the nature and extent of contamination (Dames and Moore, 1992). In 1996, Parsons Engineering Science, Inc. (Parsons) conducted an RFI to further delineate the extent of contamination identified during the 1992 VI sampling (Parsons, 1996). ICF Kaiser Engineers also performed an RFI in 1998 to further refine the understanding of the nature and extent of contamination identified during the previous investigations. Additional RFI sampling was conducted by IT Corporation/Shaw Environmental, Inc. in 2002, 2006, 2007, and 2013 to collect sufficient data to complete human health and ecological risk assessments (CB&I, 2014a).

In 2014, the USEPA and VDEQ approved the *Draft SWMU 48/49 RFI Report* (CB&I, 2014a), which developed the CMOs and RGs for the MNA program. Direct push soil borings and the installation and sampling of new and existing monitoring wells were used to: characterize the nature and extent of constituents in soil and groundwater at the SWMU 48/49 combined study area, identify the lateral and vertical extent of impacted soil and chlorinated solvents in groundwater, and characterize soil lithology and depth to groundwater and bedrock. Details of these investigations are described in Section 3.0 (Field Investigation Program) of the approved *Draft SWMU 48/49 RFI Report* (CB&I, 2014a). A potentiometric map, portraying the May 2013 groundwater levels, is provided as **Figure 3-1**. Historical data presenting the SWMU 49 COC concentrations for CT and TCE in the study area wells can be found in **Tables 3-1 through 3-5**.

The nature and extent assessment identified several volatile organic compounds (VOCs) and metals in groundwater as elevated and contributing to potential future risks. Two of the VOCs associated with potential future industrial and residential risk in the HHRA (CT and TCE) were present above USEPA's MCLs (USEPA, 2011) during the multiple groundwater sampling events at the study area. A comparison of concentrations from the mid-1990s to 2013 indicates that the majority of the VOCs are no longer present in these sampled areas and have broken down through natural processes. Analysis of the groundwater data during this roughly 20-year period shows that concentrations of CT and TCE plume have: 1) decreased overall, 2) decreased to 1 microgram per liter (µg/L) surrounding the center of the plume, and 3) decreased at least by one half in the center of the plume. The presence of daughter products (i.e., chloroform and cis-1,2-dichloroethene) in groundwater at the study area indicates that limited biological degradation of the chlorinated solvents is occurring.

The HHRA determined that CT and TCE are the primary COCs in groundwater that are contributing potential future industrial and residential risk at the SWMU 49 study area. Because the RFI demonstrated that groundwater contamination is present at concentrations associated with unacceptable human health concerns, CMOs and RGs were developed to address the concerns.

The site-specific CMO for SWMU 49 is to reduce COC concentrations to below RGs/MCLs so as to not adversely impact future beneficial use of groundwater; and to the extent practicable, a goal of restoring site groundwater to the most beneficial use. The groundwater COCs for SWMU 49 have been identified as CT and TCE. The groundwater RGs (displayed in **Table 1-1** of this Report) will be used to compare results from groundwater monitoring wells to assess the progress of the MNA.



LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- 10 ft Contour Line
- Groundwater Flow Direction
- Inferred Groundwater Contour
- Groundwater Contour
- Fence
- SWMU 49 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Water levels (in feet above mean sea level) measured in May 2013.
3) Groundwater flow direction is dashed where inferred.

N

Scale:
0 125 250 500 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 3-1
SWMU 49
Potentiometric Surface Map - May 2013
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_49_MNA_Report\RFAAP_Fig3-1_SWMU49_May_2013_GW_Contours_MNA_rpt.mxd (5/20/2015)

Table 3-1
COCs Detected in SWMU 49 Groundwater Samples - 1996 RFI

Analyte	Sample ID Sample Date	48MW1 1/20/95		48MW1 7/20/95		48MW2 1/19/95		48MW2 7/19/95		48MW3 1/20/95		48MW3 7/21/95		48MW4 7/27/95	
	RG	Result	Lab Q	Result	Lab Q	Result	Lab Q	Result	Lab Q	Result	Lab Q	Result	Lab Q	Result	Lab Q
VOCs (µg/L)															
Carbon tetrachloride	5	NT		1	U	NT		92		NT		100		1	U
Trichloroethene	5	NT		17		NT		11		NT		37		1	U

12	J	Bold outline indicates an RG exceedance.

RG = Remedial Goal
µg/L = micrograms per liter (parts per billion)
NT = Analyte not tested.
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
U = Analyte not-detected at the method reporting limit.

Table 3-2
COCs Detected in SWMU 49 Groundwater Samples - 1998 RFI

Analyte	Sample ID Sample Date	48MW1-2 4/8/98					48MW2-2 4/2/98					48MW3-2 4/2/98					48MW4-2 4/8/98				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																					
Carbon tetrachloride	5	5	U	U	*5*	*5*	140			*5*	*5*	180			*5*	*5*	5	U	U	*5*	*5*
Trichloroethene	5	8		J	*5*	*5*	18	J		*5*	*5*	33		J	*5*	*5*	5	U	U	*5*	*5*

12	J	Bold outline indicates an RG exceedance.
12	*12*	Shading in the MDL/MRL columns indicates the MDL/MRL is equal to or exceeds a criterion.

µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
RG = Remedial Goal
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers
J = Estimated concentration.
U = Analyte not detected.

Table 3-3
COCs Detected in SWMU 49 Groundwater Samples - 2006 Groundwater Data Report

Analyte	Sample ID	48MW1					48MW2					48MW3					48MW4				
	Sample Date	4/13/06					4/13/06					4/13/06					4/11/06				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																					
Carbon tetrachloride	5	1	U		*0.5*	*1*	29.2			*0.5*	*1*	51.2			*0.5*	*1*	1	U		*0.5*	*1*
Trichloroethene	5	5.5			*0.5*	*1*	3			*0.5*	*1*	7.4			*0.5*	*1*	1	U		*0.5*	*1*

12	J
12	*12*

Bold outline indicates an RG exceedance.
Shading in the MDL/MRL columns indicates the MDL exceeds a criterion.

µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
RG = Remedial Goal
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
U = Analyte not-detected at the method reporting limit.

Table 3-4
COCs Detected in SWMU 49 Study Area Groundwater Samples - 2007 RFI
Page 1 of 2

Analyte	Sample ID	48MW1					48MW2					48MW3					48MW4					48MW05					48MW06				
	Sample Date	8/29/07					8/29/07					8/29/07					8/29/07					8/30/07					8/30/07				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																														
Carbon tetrachloride	5	1	U		*0.29*	*1*	94.6			*0.29*	*1*	60.3			*0.29*	*1*	1	U		*0.29*	*1*	1	U		*0.29*	*1*	1	U		*0.29*	*1*
Trichloroethene	5	1.6			*0.38*	*1*	11.2			*0.38*	*1*	10.1			*0.38*	*1*	1	U		*0.38*	*1*	1	U		*0.38*	*1*	3.7			*0.38*	*1*

12 J Bold outline indicates an RG exceedance.

µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
RG = Remedial Goal
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
U = Analyte not-detected at the method reporting limit.

Table 3-4
COCs Detected in SWMU 49 Study Area Groundwater Samples - 2007 RFI
Page 2 of 2

Analyte	Sample ID	48MW07					49MW01					50MW01					50MW02					59MW01				
	Sample Date	8/30/07					8/29/07					8/30/07					8/30/07					8/29/07				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																										
Carbon tetrachloride	5	1	U		*0.29*	*1*	3.8			*0.29*	*1*	1	U		*0.29*	*1*	2.7			*0.29*	*1*	1	U		*0.29*	*1*
Trichloroethene	5	1	U		*0.38*	*1*	1	U		*0.38*	*1*	1	U		*0.38*	*1*	3.4			*0.38*	*1*	1	U		*0.38*	*1*

12 J Bold outline indicates an RG exceedance.

µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
RG = Remedial Goal
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
U = Analyte not-detected at the method reporting limit.

Table 3-5
VOCs Detected in SWMU 49 Study Area Groundwater Samples - 2013 Supplemental RFI

Analyte	Sample ID	13MW2					13MW3					13MW4					13MW5					48MW1					48MW2					48MW3				
	Sample Date	5/6/13					5/6/13					5/6/13					5/6/13					5/8/13					5/9/13					5/9/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																																				
1,1,1-Trichloroethane	na	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.432	J	J	*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*
1,1-Dichloroethane	na	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	1.03			*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*
1,1-Dichloroethene	na	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*
Acetone	na	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*
Carbon tetrachloride	5	0.5	U		*0.248*	*0.5*	5.63			*0.248*	*0.5*	0.5	U		*0.248*	*0.5*	0.5	U		*0.248*	*0.5*	0.5	U		*0.248*	*0.5*	82.7			*0.248*	*0.5*	73.1			*0.248*	*0.5*
Chloroform	na	0.2	U		*0.155*	*0.2*	0.453	J	J	*0.155*	*0.2*	0.2	U		*0.155*	*0.2*	0.2	U		*0.155*	*0.2*	0.2	U		*0.155*	*0.2*	5.97			*0.155*	*0.2*	7.89			*0.155*	*0.2*
cis-1,2-Dichloroethene	na	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.817	J	J	*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*
Methylene chloride	na	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*
Tetrachloroethene	na	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*
Toluene	na	0.2	U		*0.122*	*0.2*	0.2	U		*0.122*	*0.2*	0.2	U		*0.122*	*0.2*	0.2	U		*0.122*	*0.2*	2.1			*0.122*	*0.2*	1.18			*0.122*	*0.2*	0.291	J	J	*0.122*	*0.2*
Trichloroethene	5	0.2	U		*0.161*	*0.2*	1.08			*0.161*	*0.2*	1.08			*0.161*	*0.2*	0.2	U		*0.161*	*0.2*	1.9			*0.161*	*0.2*	9.75			*0.161*	*0.2*	10.7			*0.161*	*0.2*

12 J Bold outline indicates an RG exceedance.

RG = Remedial Goal developed for carbon tetrachloride and trichloroethene in CB&I, 2014.
µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
J = Value <MRL and >MDL and is considered estimated.
U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers
B = Blank contamination. Value detected in sample and associated blank.
J = Estimated concentration.
K = Estimated concentration bias high.
L = Estimated concentration bias low.
UL = Estimated concentration non-detect bias low.

Table 3-5
VOCs Detected in SWMU 49 Study Area Groundwater Samples - 2013 Supplemental RFI

Analyte	Sample ID	48MW06					49MW01					49MW02					49MW03					49MW04					49MW05					50MW02				
	Sample Date	5/7/13					5/8/13					5/9/13					5/7/13					5/6/13					5/6/13					5/8/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																																				
1,1,1-Trichloroethane	na	1.66			*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U	UL	*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.2	U		*0.123*	*0.2*	0.251	J	J	*0.123*	*0.2*
1,1-Dichloroethane	na	5.86			*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U	UL	*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.2	U		*0.171*	*0.2*	0.344	J	J	*0.171*	*0.2*
1,1-Dichloroethene	na	0.301	J	J	*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U	UL	*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*	0.5	U		*0.2*	*0.5*
Acetone	na	1	U		*0.193*	*1*	1	U		*0.193*	*1*	2.41	J	B	*0.193*	*1*	1	U	UL	*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*	1	U		*0.193*	*1*
Carbon tetrachloride	5	0.5	U		*0.248*	*0.5*	4.61			*0.248*	*0.5*	5.36			*0.248*	*0.5*	0.5	U	UL	*0.248*	*0.5*	0.664	J	J	*0.248*	*0.5*	0.5	U		*0.248*	*0.5*	0.919	J	J	*0.248*	*0.5*
Chloroform	na	0.2	U		*0.155*	*0.2*	0.193	J	J	*0.155*	*0.2*	7.79			*0.155*	*0.2*	0.2	U	UL	*0.155*	*0.2*	1.25			*0.155*	*0.2*	0.2	U		*0.155*	*0.2*	0.2	U		*0.155*	*0.2*
cis-1,2-Dichloroethene	na	9.21			*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U	UL	*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.2	U		*0.103*	*0.2*	0.373	J	J	*0.103*	*0.2*
Methylene chloride	na	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	2.3	J	L	*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*	0.5	U		*0.149*	*0.5*
Tetrachloroethene	na	0.801	J	J	*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U	UL	*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.5	U		*0.193*	*0.5*	0.255	J	J	*0.193*	*0.5*
Toluene	na	0.2	U		*0.122*	*0.2*	0.765	J	J	*0.122*	*0.2*	1.52			*0.122*	*0.2*	0.2	U	UL	*0.122*	*0.2*	0.2	U		*0.122*	*0.2*	0.2	U		*0.122*	*0.2*	0.726	J	J	*0.122*	*0.2*
Trichloroethene	5	6.25			*0.161*	*0.2*	0.2	U		*0.161*	*0.2*	0.934	J	J	*0.161*	*0.2*	0.2	U	UL	*0.161*	*0.2*	0.2	U		*0.161*	*0.2*	0.2	U		*0.161*	*0.2*	2.31			*0.161*	*0.2*

12 J Bold outline indicates an MCL exceedance.

RG = Remedial Goal developed for carbon tetrachloride and trichloroethene in CB&I, 2014.
µg/L = micrograms per liter (parts per billion)
MDL = Method Detection Limit
MRL = Method Reporting Limit
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
J = Value <MRL and >MDL and is considered estimated.
U = Analyte not-detected at the method reporting limit.

Val Q = Validation Data Qualifiers
B = Blank contamination. Value detected in sample and associated blank.
J = Estimated concentration.
K = Estimated concentration bias high.
L = Estimated concentration bias low.
UL = Estimated concentration non-detect bias low.

4.0 FIELD ACTIVITIES

The following sections provide a discussion of field activities conducted by CB&I during the baseline MNA monitoring event at SWMU 49.

The baseline groundwater monitoring consisted of a synoptic water level measurement and sampling of the 15 point of compliance (POC) monitoring wells, including one existing upgradient groundwater monitoring well, three existing cross-gradient monitoring wells, seven existing disposal area wells, and four existing downgradient wells. Field activities were conducted in accordance with the *Draft Final SWMU 49 MNA Groundwater Monitoring Work Plan* (CB&I, 2014b).

4.1 Groundwater Elevation Measurements

A round of synoptic water levels was conducted at the SWMU 49 study area prior to sampling. Water levels were recorded at each of the 15 POC monitoring wells. **Table 4-1** presents the measured depth to water levels and groundwater elevations. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the baseline monitoring event and is presented on **Figure 2-1**. It should be noted that based on previous contouring of static water level measurements of the study area groundwater levels, the water level measured at 48MW1 does not appear to be representative of recent measurements and, therefore, was excluded from contouring on **Figure 2-1**.

Table 4-1
Baseline Groundwater Monitoring Elevations

Well ID	Top of Casing Elevation (ft msl)	Depth to Water (ft bTOC)	Water Level (ft msl)	Total Depth (ft bTOC)
13MW2	1702.62	22.01	1680.61	29.0
13MW3	1694.47	15.51	1678.96	19.0
13MW4	1696.40	17.04	1679.36	24.0
13MW5	1696.40	15.54	1680.86	25.0
48MW1	1816.42	105.62*	1710.80	140.0
48MW2	1816.27	125.42	1690.85	133.7
48MW3	1808.56	98.06	1710.50	120
48MW06	1822.85	66.00	1756.85	78.0
48MW07	1833.69	47.86	1785.83	82.0
49MW01	1826.42	115.57	1710.85	121.0
49MW02	1806.29	105.94	1700.35	133.0
49MW03	1811.82	95.41	1716.41	117.0
49MW04	1703.00	21.05	1681.95	72.0
49MW05	1699.74	20.16	1679.58	36.8
50MW02	1809.63	115.72	1693.91	119.0

Notes:
* Water level does not appear to be representative.
ft bTOC – feet below top of casing
ft msl – feet above mean sea level

4.1.1 Groundwater Sampling

Groundwater samples were collected from each of the 15 POC wells on January 26-29, 2015. All groundwater samples from the baseline monitoring event were analyzed at an off-site analytical laboratory for target compound list (TCL) VOCs. In addition, all samples with the exception of 13MW5, 48MW07, 49MW03, and 49MW05, were analyzed at an off-site analytical laboratory for dissolved gasses (methane, ethene, and ethane), anions (nitrate, sulfate, and chloride), and total organic carbon (TOC). A summary of the off-site sample analyses is presented in **Table 4-2**.

Table 4-2
Sample Analysis for SWMU 49 Groundwater Monitoring

Well/Sample ID	TCL VOCs	Dissolved Gasses	Anions	Total Organic Carbon
13MW2	X	X	X	X
13MW3	X	X	X	X
13MW4	X	X	X	X
13MW5	X			
48MW1	X	X	X	X
48MW2	X	X	X	X
48MW3	X	X	X	X
48MW06	X	X	X	X
48MW07	X			
49MW01	X	X	X	X
49MW02	X	X	X	X
49MW03	X			
49MW04	X	X	X	X
49MW05	X			
50MW02	X	X	X	X

Notes:
TCL – Target compound list
VOC – Volatile organic compound

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were conducted during the groundwater sampling event. A photoionization detector (PID) reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was at the midpoint of the screen. Monitoring wells were pumped at a rate of approximately 100 milliliters per minute on average. Water quality parameters, including temperature, pH, dissolved oxygen, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. Field notes and documentation, including PID readings, water level and well depth measurements, purge rates, and water quality parameters, are presented in **Appendix A**. **Table 4-3** presents a summary of the final, stabilized reading for each well from the baseline monitoring event.

Table 4-3
SWMU 49 Baseline Monitoring Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	ORP (mV)	Temperature (°C)	Dissolved Ferrous Iron (mg/L)
13MW2	6.90	0.813	4.6	4.44	-12	12.65	< 0.2
13MW3	7.10	0.670	0.0	4.93	270	11.57	0.0
13MW4	7.29	1.09	14.3	0.03	234	12.58	0.5
13MW5	7.12	0.569	7.6	2.72	274	13.31	0.0
48MW1	7.50	0.580	16.2	2.71	191	11.97	0.0
48MW2	7.25	0.575	43.6	7.28	222	13.91	0.0
48MW3	7.23	0.752	11.6	3.78	280	11.54	0.0
48MW06	7.29	1.16	17.4	1.36	221	14.06	0.0
48MW07	8.02	0.211	18.9	10.18	281	13.13	0.0
49MW01	7.35	0.537	18.4	4.21	210	13.75	0.0
49MW02	7.52	0.567	45.2	0	77	8.59	0.0
49MW03	7.66	0.386	17.3	9.80	302	12.49	0.0
49MW04	7.46	0.689	0.0	3.63	-44	12.40	< 0.2
49MW05	7.04	0.696	16.8	2.16	227	13.20	0.3

Notes:
°C – degrees Celsius
mg/L – milligrams per liter
mS/cm – milliSiemens per centimeter
mV – millivolts
NTU – Nephelometric turbidity unit
ORP – Oxidation-reduction potential

Measurements conducted for SWMU 49 generally showed aerobic conditions for groundwater. Levels of dissolved oxygen in the wells ranged from 0 to 10.18 mg/L. ORP measurements in the wells ranged from -44 to 302 mV. Levels of pH were generally in the neutral range with measurements ranging from 6.90 to 8.02 standard units. Specific conductance measurements in the wells ranged from 0.211 to 1.16 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained at 100 milliliters per minute during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. Chain-of-custody forms and temperature blanks accompanied the samples at all times. Copies of the chain-of-custody forms are provided in **Appendix B**.

4.1.2 Quality Control Samples

Quality control samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [49TM01 (well 50MW02) and 49TM02 (well 48MW3) (see **Table 4-2** for analytes)] obtained during the baseline round of groundwater sampling. Matrix spike/matrix spike duplicates (MS/MSDs) were collected at a rate of 5 percent. MS/MSD samples were collected at wells 13MW2 and 49MW03 for the analytes shown in **Table 4-2**.

One equipment rinse blank was collected during the baseline monitoring event. Equipment rinse blanks were collected by pouring de-ionized ultra-filtered water over decontaminated sampling equipment and into laboratory supplied bottles. Rinse blanks are collected for the same suite of parameters as the samples. Results of the quality assurance/quality control (QA/QC) sample analysis are presented in **Appendix B**.

One equipment rinse blank was collected during the sampling event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, RB012714, was collected on January 27, 2015, by pouring de-ionized ultra-filtered water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

5.0 CHEMICAL ANALYTICAL RESULTS

5.1 Selection of Comparison Criteria

The chemical data collected during this investigation were compared to RGs selected in the approved *Draft SWMU 48/49 RFI Report* (CB&I, 2014a). **Tables 5-1 and 5-2** present the detected sample results and a summary of the baseline monitoring data, including number of RG exceedances, frequency of detection, the minimum and maximum detected concentrations, and the location of the maximum concentration.

5.2 Baseline Monitoring Groundwater Results

Fifteen groundwater monitoring wells were sampled during the baseline sampling event. Sample locations are shown on **Figure 1-2**. Groundwater samples were analyzed for TCL VOCs and MNA indicator parameters, including dissolved gasses, anions, and TOC. A duplicate sample was collected from POC monitoring wells 48MW3 and 50MW02 and analyzed for TCL VOCs and MNA indicator parameters, including dissolved gasses, anions, and TOC. Sample results for the detected VOCs are presented in **Table 5-1** and summarized in **Table 5-2**. **Figure 5-1** depicts the concentrations of CT and TCE, in comparison to the RG, for all 15 POC wells.

TCL VOCs

CT was detected in 12 of the POC wells. Concentrations exceeded the RG (5 µg/L) in three of the wells (48MW2 and 48MW3, and 49MW02). Concentrations detected above the RG ranged from 5.05 µg/L in well 49MW02 to 118 µg/L in well 48MW2. CT results are shown on **Figure 5-1.**

TCE was detected in eight of the POC wells. TCE concentrations were above the RG (5 µg/L) in two of the wells (48MW2 and 48MW3). Concentrations detected above the RG were 10.5 µg/L in well 48MW2 and 12.4 µg/L in well 48MW3. TCE results are shown on **Figure 5-1.**

cis-1,2-Dichloroethene was detected in 3 of the 15 POC wells at concentrations ranging from 0.384 to 4.86 µg/L.

Chloroform was detected in six POC wells at concentrations ranging from 0.404 to 8.37 µg/L.

Miscellaneous Analytes

As shown in **Table 4-2**, 11 of the 15 groundwater samples collected were also analyzed for miscellaneous MNA indicators (TOC, chloride, nitrate, sulfate, methane, and ethene) for the purposes of establishing a baseline concentration of theses analytes. These indicators provide insight into whether MNA is occurring, and with what driver. These baseline levels will be compared to data produced in future sampling efforts. The results of the detected miscellaneous analytes are presented in **Table 5-1** and summarized in **Table 5-2**.

TOC was only detected in well 48MW06 at a concentration of 1,640 µg/L. Chloride was detected in all 11 wells at concentrations ranging from 2,220 to 6,400 µg/L. Nitrate was detected in 10 of the 11 POC wells at concentrations ranging from 47.6 to 11,500 µg/L. Sulfate was detected in 10 of the 11 POC wells at concentrations ranging from 16,800 to 275,000 µg/L. Methane and ethane were both only detected in one well (49MW02); the concentration of methane was 1.54 µg/L, and the concentration of ethene was 1.4 µg/L.

Figure 5-1
Concentrations of CT and TCE in SWMU 49 POC Wells

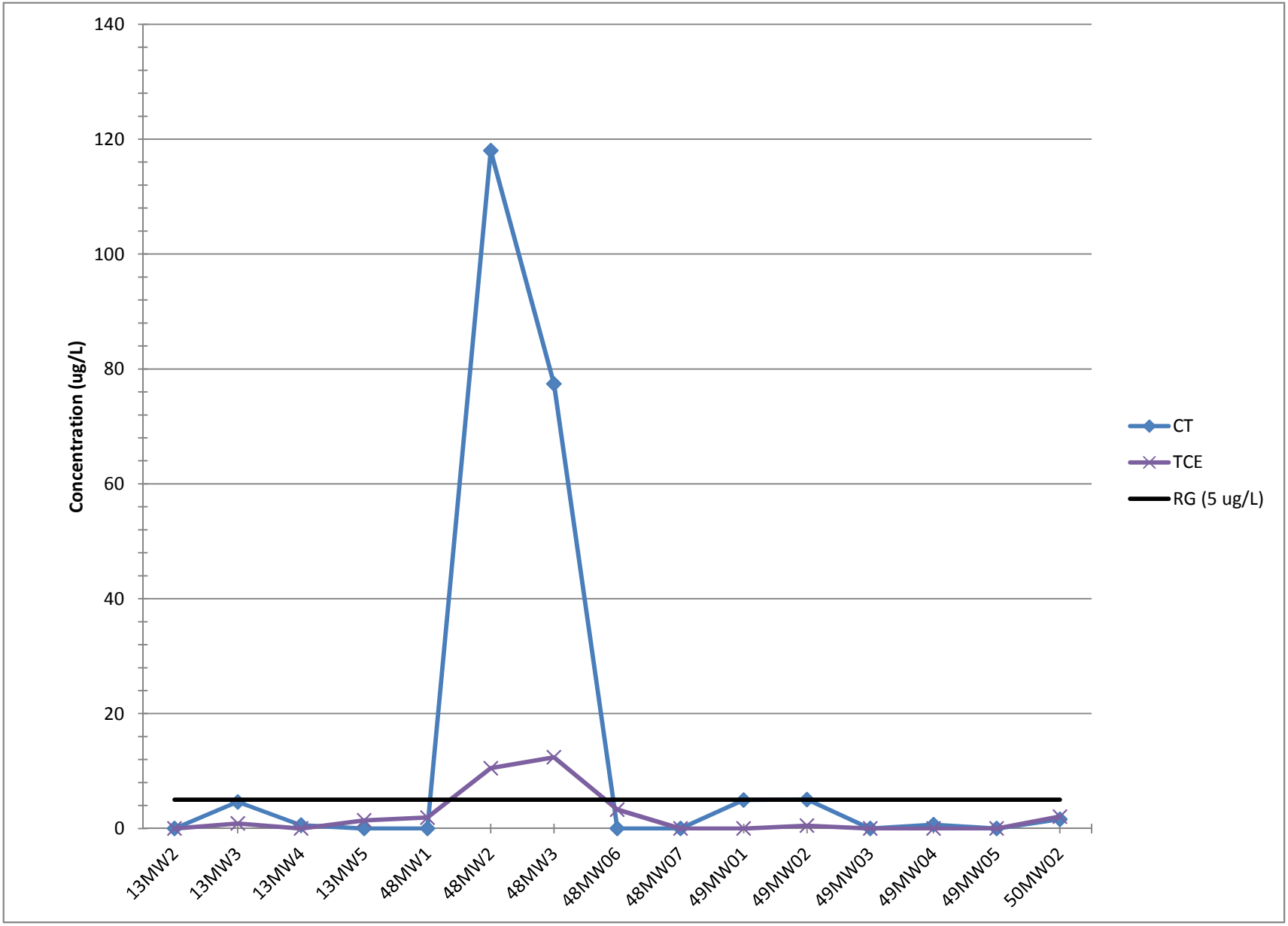


Table 5-1
Analytes Detected in Baseline Monitoring Groundwater Samples
Page 1 of 2

Analyte	Sample ID / Sample Date	13MW2 1/26/15					13MW3 1/26/15					13MW4 1/26/15					13MW5 1/26/15					48MW1 1/28/15					48MW2 1/28/15					48MW3 1/27/15					48MW06 1/29/15				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																																								
1,1,1-Trichloroethane	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.454	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.691	DJ	J	*0.5*	*1*
1,1-Dichloroethane	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.908	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	4.28	D		*0.5*	*1*
Acetone	na	5	U		*2.5*	*5*	5	U		*2.5*	*5*	5	U		*2.5*	*5*	5	U		*2.5*	*5*	5	U		*2.5*	*5*	5	U		*2.5*	*5*	5	XU		*2.5*	*5*	27.8	D	B	*5*	*10*
Bromoform	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	XU		*0.5*	*1*
Bromomethane	na	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	NU		*0.5*	*1*	2	U		*1*	*2*
Carbon tetrachloride	5	0.5	U		*0.25*	*0.5*	4.62			*0.25*	*0.5*	0.592	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	XU		*0.25*	*0.5*	118	X	J	*0.25*	*0.5*	77.4			*0.25*	*0.5*	1	XU		*0.5*	*1*
Chloroform	na	0.5	U		*0.25*	*0.5*	0.47	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	7.46			*0.25*	*0.5*	8.37			*0.25*	*0.5*	1	U		*0.5*	*1*
cis-1,2-Dichloroethene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.914	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	4.86	D		*0.5*	*1*
Dibromochloromethane	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	XU		*0.25*	*0.5*	1	U		*0.5*	*1*
Ethylbenzene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.469	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*
m- & p-Xylene	na	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	0.535	J	J	*0.5*	*1*	1.32	J	J	*0.5*	*1*	0.736	J	J	*0.5*	*1*	2	U		*1*	*2*
o-Xylene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.285	J	J	*0.25*	*0.5*	0.919	J	J	*0.25*	*0.5*	0.495	J	J	*0.25*	*0.5*	1	U		*0.5*	*1*
Tetrachloroethene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.709	DJ	J	*0.5*	*1*
Trichloroethene	5	0.5	U		*0.25*	*0.5*	0.883	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1.42			*0.25*	*0.5*	1.91			*0.25*	*0.5*	10.5			*0.25*	*0.5*	12.4			*0.25*	*0.5*	3.29	D		*0.5*	*1*
Misc. (µg/L)																																								
Total Organic Carbon	na	2500	U		*1250*	*2500*	2500	U		*1250*	*2500*	2500	U		*1250*	*2500*	NT					2500	U		*1250*	*2500*	2500	U		*1250*	*2500*	2500	U		*1250*	*2500*	1640	J	J	*1250*	*2500*
Chloride	na	2750			*170*	*330*	3880			*170*	*330*	11500			*170*	*330*	NT					3100			*170*	*330*	2650			*170*	*330*	2220			*170*	*330*	9360	D		*340*	*660*
Nitrate (as N)	na	71.5	J	J	*33*	*100*	1660			*33*	*100*	100	U		*33*	*100*	NT					1350			*33*	*100*	754			*33*	*100*	6400			*33*	*100*	5880			*33*	*100*
Sulfate	na	45900			*330*	*1000*	126000			*330*	*1000*	23800			*330*	*1000*	NT					58000			*330*	*1000*	16800			*330*	*1000*	29800			*330*	*1000*	275000	D		*660*	*2000*
Methane	na	2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*	NT					2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*
Ethene	na	2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*	NT					2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*	2	U		*1*	*2*

12 Bold outline indicates an RG exceedance.

RG = Remedial Goal developed for carbon tetrachloride and trichloroethene in CB&I, 2014.
µg/L = micrograms per liter (parts per billion)
CCV = Continuing Calibration Verification
ICV = Initial Calibration Verfication
MDL = Method Detection Limit
MRL = Method Reporting Limit
na = not applicable
NT = Analyte not tested.
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
D = Sample was run at a dilution.
J = Value <MRL and >MDL and is considered estimated.
N = Matrix Spike/Matrix Spike Duplicate accuracy and/or precision were outside criteria.
U = Analyte not-detected at the method reporting limit.
X = The associated ICV/CCV exceeded the upper control limit.

Val Q = Validation Data Qualifiers
B = Blank contamination. Value detected in sample and associated blank.
J = Estimated concentration.

Table 5-1
Analytes Detected in Baseline Monitoring Groundwater Samples
Page 2 of 2

Analyte	Sample ID	48MW07					49MW01					49MW02					49MW03					49MW04					49MW05					50MW02				
	Sample Date	1/29/15					1/28/15					1/27/15					1/28/15					1/26/15					1/26/15					1/27/15				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
VOCs (µg/L)																																			
1,1,1-Trichloroethane	na	0.5	U		*0.25*	*0.5*	0.262	J	J	*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*
1,1-Dichloroethane	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.313	J	J	*0.25*	*0.5*
Acetone	na	5	U		*2.5*	*5*	5	U		*2.5*	*5*	14	XDJ	B	*5*	*10*	5	U		*2.5*	*5*	5	U		*2.5*	*5*	18.6	DJ	B	*5*	*10*	5	XU		*2.5*	*5*
Bromoform	na	0.5	XU		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*
Bromomethane	na	1	U		*0.5*	*1*	1	U		*0.5*	*1*	2	U		*1*	*2*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	2	U		*1*	*2*	1	U		*0.5*	*1*
Carbon tetrachloride	5	0.5	XU		*0.25*	*0.5*	4.97	X	J	*0.25*	*0.5*	5.05	D		*0.5*	*1*	0.5	XU		*0.25*	*0.5*	0.662	J	J	*0.25*	*0.5*	1	U		*0.5*	*1*	1.62			*0.25*	*0.5*
Chloroform	na	0.5	U		*0.25*	*0.5*	0.404	J	J	*0.25*	*0.5*	1.55	DJ	J	*0.5*	*1*	0.5	U		*0.25*	*0.5*	1.46			*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*
cis-1,2-Dichloroethene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.384	J	J	*0.25*	*0.5*
Dibromochloromethane	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	XU		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	XU		*0.25*	*0.5*
Ethylbenzene	na	0.5	U		*0.25*	*0.5*	0.262	J	J	*0.25*	*0.5*	1.13	DJ	J	*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*
m- & p-Xylene	na	1	U		*0.5*	*1*	0.69	J	J	*0.5*	*1*	4.06	D		*1*	*2*	1	U		*0.5*	*1*	1	U		*0.5*	*1*	2	U		*1*	*2*	0.804	J	J	*0.5*	*1*
o-Xylene	na	0.5	U		*0.25*	*0.5*	0.544	J	J	*0.25*	*0.5*	2.91	D		*0.5*	*1*	0.296	J	J	*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.542	J	J	*0.25*	*0.5*
Tetrachloroethene	na	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	0.311	J	J	*0.25*	*0.5*
Trichloroethene	5	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	0.501	DJ	J	*0.5*	*1*	0.5	U		*0.25*	*0.5*	0.5	U		*0.25*	*0.5*	1	U		*0.5*	*1*	2.08			*0.25*	*0.5*
Misc. (µg/L)																																			
Total Organic Carbon	na	NT					2500	U		*1250*	*2500*	2500	U		*1250*	*2500*	NT					2500	U		*1250*	*2500*	NT					2500	U		*1250*	*2500*
Chloride	na	NT					6030			*170*	*330*	3450			*170*	*330*	NT					5160			*170*	*330*	NT					7270			*170*	*330*
Nitrate (as N)	na	NT					303			*33*	*100*	47.6	J	J	*33*	*100*	NT					249	J	J	*33*	*100*	NT					2060			*33*	*100*
Sulfate	na	NT					1000	U		*330*	*1000*	26600			*330*	*1000*	NT					53600			*330*	*1000*	NT					73200			*330*	*1000*
Methane	na	NT					2	U		*1*	*2*	1.54	J	J	*1*	*2*	NT					2	U		*1*	*2*	NT					2	U		*1*	*2*
Ethene	na	NT					2	U		*1*	*2*	1.4	J	J	*1*	*2*	NT					2	U		*1*	*2*	NT					2	U		*1*	*2*

12 Bold outline indicates an RG exceedance.

RG = Remedial Goal developed for carbon tetrachloride and trichloroethene in CB&I, 2014.
µg/L = micrograms per liter (parts per billion)
CCV = Continuing Calibration Verification
ICV = Initial Calibration Verfication
MDL = Method Detection Limit
MRL = Method Reporting Limit
na = not applicable
NT = Analyte not tested.
VOC = Volatile Organic Compound

Lab Q = Lab Data Qualifiers
D = Sample was run at a dilution.
J = Value <MRL and >MDL and is considered estimated.
N = Matrix Spike/Matrix Spike Duplicate accuracy and/or precision were outside criteria.
U = Analyte not-detected at the method reporting limit.
X = The associated ICV/CCV exceeded the upper control limit.

Val Q = Validation Data Qualifiers
B = Blank contamination. Value detected in sample and associated blank.
J = Estimated concentration.

Table 5-2
Summary of Analytes Detected in Baseline Monitoring Groundwater Samples

Analyte	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
VOCs (µg/L)							
1,1,1-Trichloroethane	na	na	3	15	0.262	0.691	48MW06
1,1-Dichloroethane	na	na	3	15	0.313	4.28	48MW06
Acetone	na	na	5	15	5	27.8	48MW06
Bromoform	na	na	2	15	0.5	1	48MW06
Bromomethane	na	na	1	15	1	1	48MW3
Carbon tetrachloride	5	3	12	15	0.5	118	48MW2
Chloroform	na	na	6	15	0.404	8.37	48MW3
cis-1,2-Dichloroethene	na	na	3	15	0.384	4.86	48MW06
Dibromochloromethane	na	na	3	15	0.5	1	49MW02
Ethylbenzene	na	na	3	15	0.262	1.13	49MW02
m- & p-Xylene	na	na	6	15	0.535	4.06	49MW02
o-Xylene	na	na	7	15	0.285	2.91	49MW02
Tetrachloroethene	na	na	2	15	0.311	0.709	48MW06
Trichloroethene	5	2	8	15	0.501	12.4	48MW3
Misc. (µg/L)							
Total Organic Carbon	na	na	1	11	1640	1640	48MW06
Chloride	na	na	11	11	2220	11500	13MW4
Nitrate (as N)	na	na	10	11	47.6	6400	48MW3
Sulfate	na	na	10	11	16800	275000	48MW06
Methane	na	na	1	11	1.54	1.54	49MW02
Ethene	na	na	1	11	1.4	1.4	49MW02

µg/L = micrograms per liter

na = not applicable

RG = Remedial Goal

VOC = Volatile Organic Compound

6.0 SUMMARY AND CONCLUSIONS

Fifteen groundwater monitoring wells were sampled in the SWMU 49 study area in January 2015 to provide a baseline analysis of the COCs, CT and TCE, and their daughter product concentrations. Sample results were evaluated to determine whether MNA is continuing to occur at the site. This report presents and summarizes the results of the baseline sampling event.

Consistent with the TCL VOC results from the most recent sampling event in May 2013, the highest concentrations of CT and TCE were observed in wells 48MW2 and 48MW3, where the center of the plumes is located. The CT and TCE plumes are small and isolated and have not changed in size or shape since May 2013. As discussed in CB&I (2014a) and illustrated on **Figure 6-1**, the CT plume is oval in shape, approximately 250 ft in length (north to south) and 680 ft wide (east to west), and is delineated in all directions. The center of the plume (highest detected concentrations) is located approximately 205 ft southeast of SWMU 49. The upgradient edge of the plume is located approximately 250 ft to the northwest from the center of the plume. As discussed in CB&I (2014a) and illustrated on **Figure 6-2**, the TCE plume is triangular in shape, is approximately 560 ft in length (north to south) and 580 ft wide (east to west), and is delineated in all directions. The center of the plume (highest detected concentrations) is located approximately 210 ft southeast of SWMU 49. The upgradient edge of the plume is located approximately 300 ft to the northwest from the center of the plume and extends into SWMU 48.

Since May 2013, CT and TCE concentrations have remained similar across the SWMU 49 study area. The only RG exceedances of CT and TCE observed in January 2015 were in wells 48MW2 and 48MW3; CT also slightly exceeded the RG in well 49MW02.

An evaluation of the effectiveness of remedy will be performed after the second year of sampling. It is recommended that future sampling rounds be conducted under another contract to continue to monitor the concentrations of CT, TCE, and their daughter products in groundwater at the SWMU 49 study area.

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Fence
- Water Feature
- 10 ft Contour Line
- Carbon Tetrachloride Isopleth
- SWMU 49 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Isopleth concentrations are in ug/L.
3) Sample results obtained in January 2015.

N

Scale:
0 125 250 500 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 6-1
SWMU 49
Carbon Tetrachloride Isopleths - January 2015
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford MMA\GIS Documents\Project Maps\SWMU 49 MNA Report\RFAAP Fig6-1 SWMU49 2015 CTC GW Plume MNA rpt.mxd (5/27/2015)

LEGEND

- Monitoring Well (Sampled)
- Monitoring Well (Not Sampled)
- Fence
- Water Feature
- 10 ft Contour Line
- Trichloroethene Isopleth
- SWMU 49 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Isopleth concentrations are in ug/L.
3) Sample results obtained in January 2015.

N

Scale:
0 125 250 500 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 6-2
SWMU 49
Trichloroethene Isopleths - January 2015
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford MMA\GIS Documents\Project Maps\SWMU 48 49 RFI\RFAAP Fig6-2 SWMU49 2015 TCE GW Plume MNA rpt.mxd (5/27/2015)

7.0 REFERENCES

CB&I Federal Services LLC (CB&I), 2014a. *SWMU 48/49 RCRA Facility Investigation Report*. Radford Army Ammunition Plant, Virginia. Draft Report. January.

CB&I Federal Services LLC (CB&I), 2014b. *SWMU 49 Monitored Natural Attenuation Groundwater Monitoring Work Plan*. Radford Army Ammunition Plant, Radford, Virginia. Draft Final document. October.

Dames and Moore, 1992. *Final Draft VI Report for the Radford Army Ammunition Plant, Virginia*. Prepared for the U.S. Army Toxic and Hazardous Materials Agency.

IT Corporation (IT), 2001. *Facility-Wide Background Study*. Radford Army Ammunition Plant, Virginia. Final Report. Delivery Order No. 0008, Contract No. DACA31-94-D-0064.

Parsons Engineering Science, Inc. (Parsons), 1996. *RCRA Facility Investigation for Solid Waste Management Units 17, 31, 48, and 54 at Radford Army Ammunition Plant, Virginia.* Prepared for U.S. Army Environmental Center.

URS Corporation (URS), 2003. *Final Master Work Plan, Quality Assurance Plan, Health and Safety Plan*. Radford Army Ammunition Plant, Radford, Virginia. Prepared for the U.S. Army Corps of Engineers, Baltimore District. August.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1987. *RCRA Facility Assessment of Radford Army Ammunition Plant.*

U.S. Environmental Protection Agency (USEPA), 2011. *2011 Edition of the Drinking Water Standards and Health Advisories*. Office of Water, EPA 822-R-06-013. Winter 2011.